National River Conservation Directorate
Department of Water Resources,
River Development and Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

STATUS OF AERIAL/DRONE SURVEY OF CAUVERY RIVER BASIN

September 2024

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National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development and Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Cauvery River Basin Management and Studies (cCauvery)

The Centre for Cauvery River Basin Management and Studies (cCauvery) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IISc Bengaluru and NIT Tiruchirappalli, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cCauvery is committed to restoring and conserving the Cauvery River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.ccauvery.org

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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

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Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

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Contents

List of Figures

List of Tables

Abbreviations/ Acronyms

°	Degree
e.g.	For example
km	Kilometre
m	Metre
nm	Nanometre
sq.	Square
CAPF	Central Armed Police Forces
CRB	Cauvery River Basin
CSV	Comma-Separated Values
DEM	Digital Elevation Model
DGCA	Directorate General of Civil Aviation
DGPS	Differential Global Positioning System
DSM	Digital Surface Model
FOSS	Free and Open-Source Software
FPOs	Farmer Producer Organizations
GCP	Ground Control Point
GCS	Geographic Coordinate System
GIS	Geographic Information System
HAB	Harmful Algae Bloom
ICAR	Indian Council of Agricultural Research
ICFOSS	International Centre for Free and Open-Source Software
IISc	Indian Institute of Science
ILIMS	Integrated Land Information and Management System
ISRO	Indian Space Research Organization
KML	Keyhole Markup Language
KVKs	Krishi Vigyan Kendras
LiDAR	Light Detection and Ranging
MoPR	Ministry of Panchayati Raj
OAM	Open Aerial Map
PCs	Personal Computer
PCS	Projected Coordinate System
POC	Proof of Concept
PPK	Post-Processed Kinematic
RGB	Red, Green, Blue
RMSE	Root Mean Square Error
RTK	Real Time Kinematic
SAUs	State Agricultural Universities
SfM	Structure from Motion
SoI	Survey of India
SVAMITVA	Survey of Villages and Mapping with Improvised Technology in Village Areas
TIR	Thermal Infrared
UAVs	Unmanned Aerial Vehicles
VTOL	Vertical Take-Off and Landing

1. Introduction

Aerial and drone surveys have become indispensable tools for environmental monitoring, resource management, and infrastructure development due to their ability to efficiently capture high-resolution imagery and data over large areas. In the Cauvery River Basin (CRB), unmanned aerial vehicles (UAVs) play a critical role in providing detailed topographic and spatial data essential for effective water resource management, agricultural optimization, and environmental conservation. These surveys generate 3D models, orthophotos, and maps, offering valuable insights into the basin's complex hydrological and ecological systems. Table 1 compares various aerial surveying technologies, highlighting the advantages of UAVs for such applications.

The Cauvery Basin faces challenges such as seasonal water shortages, flooding, and land-use changes. Aerial surveys are particularly useful in addressing these issues, enabling real-time monitoring of river flows, reservoir levels, and flood-prone areas to inform flood control measures and water distribution systems (Vélez-Nicolás et al., 2021). In agriculture, UAVs provide precise field mapping to optimize irrigation, reduce water waste, and boost productivity in a region heavily reliant on its water resources (Raj et al., 2021). Table 2 summarizes commonly used UAV sensors for hydrological applications, demonstrating the versatility of drone technology. The technology has also proven effective in mining operations (Peterman & Mesarič, 2012) and ecosystem mapping (Boon, 2016). Additionally, drone-based aerial photography aids in sedimentation studies of rivers and reservoirs, ensuring water quality and storage capacity are maintained. Drone technology also supports land formalization efforts under India's SVAMITVA (Survey of Villages and Mapping with Improvised Technology in Village Areas) scheme, adding public value to land administration and management.

Beyond water management, UAVs are crucial for monitoring environmental changes, including deforestation, wetland degradation, and land-use alterations impacting the basin's ecosystems. They also contribute to infrastructure development, providing precise geospatial data for projects like dam construction, canal excavation, and groundwater recharge identification. These advancements not only enhance the efficiency of development efforts but also promote long-term sustainability of the Cauvery Basin's natural resources.

Incorporating aerial and drone surveys into the management of the Cauvery Basin is a forward-thinking strategy that supports informed decision-making, environmental conservation, and sustainable regional development, ensuring a more resilient future for both the basin's water resources and its communities.

Table 1. Comparison of aerial surveying technologies

Technology	Description	Cost	Coverage
Aerial Photographs	Traditional aerial photography uses manned aircraft to capture large-scale images, providing extensive area coverage. Typically requires post-processing to create terrain models.	High	High
UAV-based Images	Drones capture high-resolution images for various applications, providing flexible coverage and quick data acquisition without the need for extensive post-processing.	Low	High
UAV-based Photogrammetry	Unmanned Aerial Vehicles (drones) equipped with cameras capture aerial imagery that, after post-processing, can be used to generate detailed terrain models. This method offers flexibility in coverage and is more cost-effective.	Low	High
UAV-based LiDAR	Drones equipped with Light Detection and Ranging (LiDAR) sensors provide high-resolution mapping of terrain, offering greater flexibility for smaller areas compared to manned aircraft. Post-processing required for data analysis.	High	Medium

2. Summary of Existing Literature on Drone/UAV/Aerial Survey applications in the CRB

Hemamalini et al. (2022) conducted a drone-based aerial survey to assess air quality parameters in and around solid waste dump yards, residential areas, and industrial zones in the Manali district of Chennai. Their study highlighted the detrimental impact of waste disposal and industrial emissions on local air quality. Similarly, Ranganathan et al. (2023) employed drones to monitor air quality at the Kodungaiyur dump yard in Chennai, Tamil Nadu, an area that necessitates environmental monitoring due to elevated pollution levels and health risks associated with unsegregated waste. Their findings emphasized the urgent need for real-time air quality monitoring systems using Geographic Information System (GIS) technology to provide accurate and timely information on air quality levels.

Table 2. Summary and examples of sensors frequently used with UAV for hydrological applications
(**Source:** Vélez-Nicolás et al., 2021)

Sensor type	Spectral ranges (nm)	Example cameras from cited works	Hydrological applications	Main advantages	Main disadvantages
RGB	~400-700	Canon Powershot G5, Canon EOS (Lejot et al., 2007) Zenmuse X3, FC350 (Woodget et al., 2019) OLYMPUS EP-2 (Gentile et al., 2016) Nikon D500/D5100 (Flener et al., 2013)	Visual analysis, bathymetry, digital elevation model (DEM) photogrammetry, water stage measurement, flood monitoring, particle velocimetry, harmful algae bloom (HAB) monitoring, surface mapping and classification.	a. Offers a wide range of prices, resolutions, and weights based on the model. b. Capable of video capture. c. Easily integrates with various platforms.	a. Limited spectral resolution makes them unsuitable for many applications. b. Highly sensitive to environmental and lighting conditions. c. May lack geometric and radiometric calibration.
Multispectral	~400-1000	Rededge Micasense (Castro et al., 2020)	HAB monitoring, bathymetry, flood monitoring, interactions between surface water and groundwater, wetland/river mapping, assessing river/lake trophic status, surface/material identification.	a. Broader range of applications compared to RGB sensors, enabling discrimination and identification of various materials. b. Some offer radiometric calibration. c. Facilitate geometric reconstruction.	a. Relatively high costs. b. Detect radiation in a limited number of broad wavelength bands, which constrains their applications. c. Currently not optimized for aquatic environments.

				d. Allow for sub-decimetric mapping.	d. Limited compatibility with UAVs.
Hyperspectral	~500-2500	Rikola 2D (Gentile et al., 2016) Nano Hyperspec (Legleiter et al., 2019)	Bathymetry, HAB monitoring, assessing river/lake trophic status, flood monitoring, water quality monitoring, wetland/river mapping, surface/material identification.	High spectral resolution with numerous narrow contiguous spectral bands enhances material discrimination and identification.	a. High costs. b. Larger sensor size. c. Requires specialized software. d. Lower signal-to-noise ratio.
Thermal Infrared	~8000-14,000	ThermoMAP (Collas et al., 2019) DJI Zenmuse XT (Dugdale et al., 2019) ICI Mirage 640 (Kinzel et al., 2019) FLIR TAU2 640 (Mallast et al., 2019)	Mapping river/lake temperatures, identifying surface water-groundwater discharge, thermal plume detection, river discharge monitoring.	a. Validation is not necessary if only relative temperatures are required. b. Generally lower cost. c. Available in a variety of models and resolutions.	a. Temperature drift can be problematic. b. Radiation from near-bank objects may affect sensor performance, leading to misinterpretations. c. Requires radiometric corrections. d. Interpretation of thermal infrared (TIR) imagery can be complex and requires expertise. e. Highly sensitive to observation angles less than 30° and changes in surface roughness.

UAS LiDAR	~500-900	Phoenix Scout SL1 (Chen et al., 2020) ASTRALiTE edge (Kinzel et al., 2019)	Bathymetry, 3D mapping, water stage monitoring, flood assessment.	a. Less affected by environmental conditions. b. Provides direct geometric measurements. c. Capable of distinguishing vegetation effects.	a. Effectiveness is constrained by water clarity and bottom surface reflectivity. b. Typically involves high costs. c. Limited compatibility with UAV models. d. Ground filtering corrections are necessary. e. Highly dependent on precise dynamic positioning systems.

Sundhar et al. (2022) applied drone technology to identify and analyze vulnerable mosquito breeding sites along the Buckingham Canal in Chepauk, Chennai. Their results facilitated targeted interventions for mosquito control, thereby mitigating the risk of vector-borne diseases such as dengue and malaria. Extending the application of drones further, Lukambagire et al. (2024) supported sustainable fishing practices within the coastal community of Alappad Panchayat in Kollam district, Kerala.

Shetty et al. (2023) utilized UAV technology to assess total sediment deposition in Kavoor Lake, Karnataka. This evaluation aimed to determine the lake's condition and quantify its benefits to crop productivity before and after the construction of a bund. Additionally, Stalin and Kumar (2021) conducted a UAV-based aerial survey and DGPS observations for volumetric audits and environmental impact assessments at a sand quarry in Neyvasal, Cuddalore district, Tamil Nadu. Bupathy et al. (2021) utilized drones to capture aerial images of a brinjal (Solanum melongena) field in Vedasandur, Tamil Nadu, for the purpose of monitoring crop growth.

Shenbagaraj et al. (2021) employed UAV remote sensing techniques to analyze shoreline changes in Cuddalore District, Tamil Nadu, from 1989 to 2017, quantifying the rate of shoreline change over approximately 8.7 km. In a related study, Hemalatha et al. (2024) employed aerial photographs to evaluate urban sprawl in Chennai, Tamil Nadu, revealing a significant reduction in open land, green spaces, and water bodies because of rapid urbanization. Veeravalli et al. (2023) conducted a UAV-based survey to create detailed topographical data for Velliyamkallu Island in Kozhikode, Kerala. The findings from their survey lay the groundwork for the formulation of informed, sustainable, and effective development strategies applicable to Velliyamkallu and similar regions.

Shubhasree et al. (2022) utilized publicly available video data to create an annotated dataset of flooded areas in Kerala, categorized into urban and suburban regions. This dataset provides critical information for flood monitoring and management. Krishna et al. (2024) proposed an integrated UAV and Structure from Motion (SfM) approach to rectify DEM inaccuracies caused by dense vegetation, enhancing the accuracy of landslide simulations and volumetric analysis for post-disaster management in Pettimudi, Kerala. Focusing on the Western Ghats, the study highlighted geomorphological factors such as concave curvature, colluvium deposits, and paleo landslide evidence that contribute to landslide susceptibility. The research emphasizes the need for detailed assessments and mitigation strategies, especially considering recent disasters like the 2020 Pettimudi landslide, which resulted in 70 fatalities.

On June 5, 2017, India witnessed its inaugural drone-based seeding test along the Pinakini River in the Gauribidanur region of Karnataka. This pioneering initiative, spearheaded by scientists from the Indian Institute of Science (IISc) in Bengaluru, aimed to restore a vast area of 4,000 hectares in the Doddaballapur hills (https://www.thenewsminute.com/news/how-iisc-scientists-areseed-bombing-barren-land-karnataka-using-drones-64155).

Additionally, IISc developed a portable drone corridor known as CORRIDRONE, which received partial funding from the Robert Bosch Center for Cyber-Physical Systems (https://corridrone.com/). This innovative air corridor design features a multi-lane geometry and adaptive dynamic fencing, facilitating efficient execution of quick missions. Furthermore, CORRIDRONE enhances flight planning by incorporating compliance levels for UAVs.

In conclusion, the insights gained from these studies underscore the transformative potential of drone technology across various sectors, including environmental monitoring and agriculture. As demonstrated, drones not only provide critical data for assessing air quality and vector control but also enhance sustainable practices in fishing communities. The collective findings highlight the importance of continued investment in drone technology and education, as they significantly contribute to informed decision-making and improved outcomes for both farmers and communities.

3. Drone Operational Zones in the CRB Under the Drone Rules, 2021

The Drone Rules, 2021, classify Indian airspace into three main zones based on drone operation restrictions (https://digitalsky.dgca.gov.in/):

i. Green Zone

These areas have minimal restrictions, allowing drones to fly up to 400 feet (120 meters) without special permissions. Most regions, including large parts of the CRB, fall under this category.

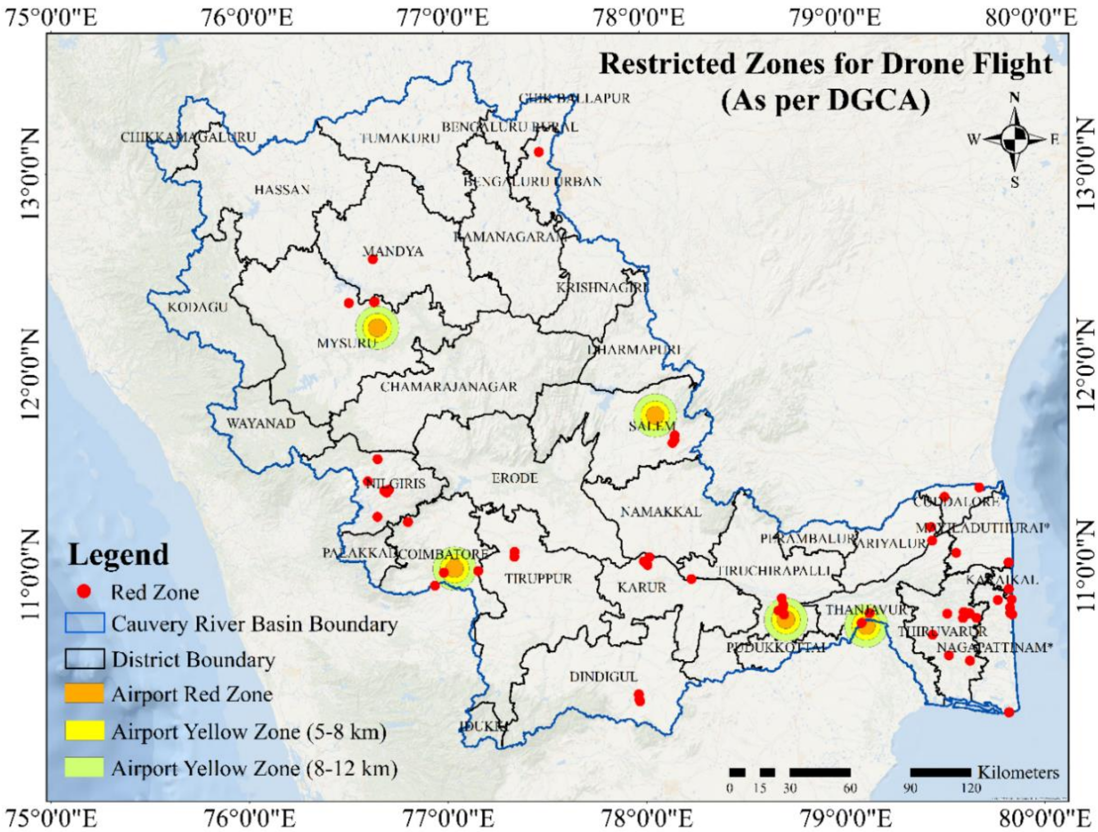

Fig. 1. Restricted Zones for Drone Flight under the Drone Rules, 2021
(**Source:** Digital Sky Platform | https://digitalsky.dgca.gov.in/airspace-map/#/app)

ii. **Yellow Zone**

This is controlled airspace where specific permissions are required for drone operations. Yellow zones are typically located near sensitive areas like airports, military installations, or strategic zones, with applicable height and operational restrictions.

iii. **Red Zone**

Designated as no-fly zones, drone operations are strictly prohibited here unless exceptional permission is granted by the government. These areas include high-security locations and critical infrastructure.

In the CRB, restricted zones exist due to security, industrial, and critical infrastructure concerns. Key examples include:

- **Airport Zones**: Areas around Mysuru, Salem, Coimbatore, Thanjavur, and Trichy International Airports are surrounded by red and yellow zones, limiting drone activities within specific radii.
- **Security Zones**: Locations near military installations, Central Armed Police Forces (CAPF) camps, and state police headquarters are designated as red or yellow zones due to security risks.
- **Industrial Zones**: Industrial hubs like the Neyveli Lignite Corporation and important power plants in Karnataka and Tamil Nadu have restrictions on drone flights due to safety and security protocols.
- **Critical Infrastructure**: Vital structures such as the Mettur and Krishna Raja Sagara Dams, along with major ports in the basin, are highly sensitive areas with strict drone regulations to ensure their protection.
- **Religious and Cultural Sites**: Prominent temples and heritage locations, including the Ranganathaswamy Temple in Srirangapatna and the Brihadeeswarar Temple in Thanjavur, are under restricted zones to preserve cultural integrity and avoid disturbances.

For successful drone surveys in the CRB, particularly for water quality assessments, hazard mapping, and river conservation efforts, it is essential to prioritize areas outside restricted zones. Additionally, securing necessary permissions for drone operations within or near restricted zones should be proactively addressed to ensure compliance with regulations and optimize operational efficiency.

4. UAV data sources for CRB

4.1. GEONADIR

This platform serves as a global repository for drone data, allowing users to both contribute and access openly licensed UAV imagery. It offers datasets from around the world, including India, where users can explore available data or contribute their own (https://geonadir.com/). It provides some open-source images, none are related to the CRB, as illustrated in Figs. 2 and 3.

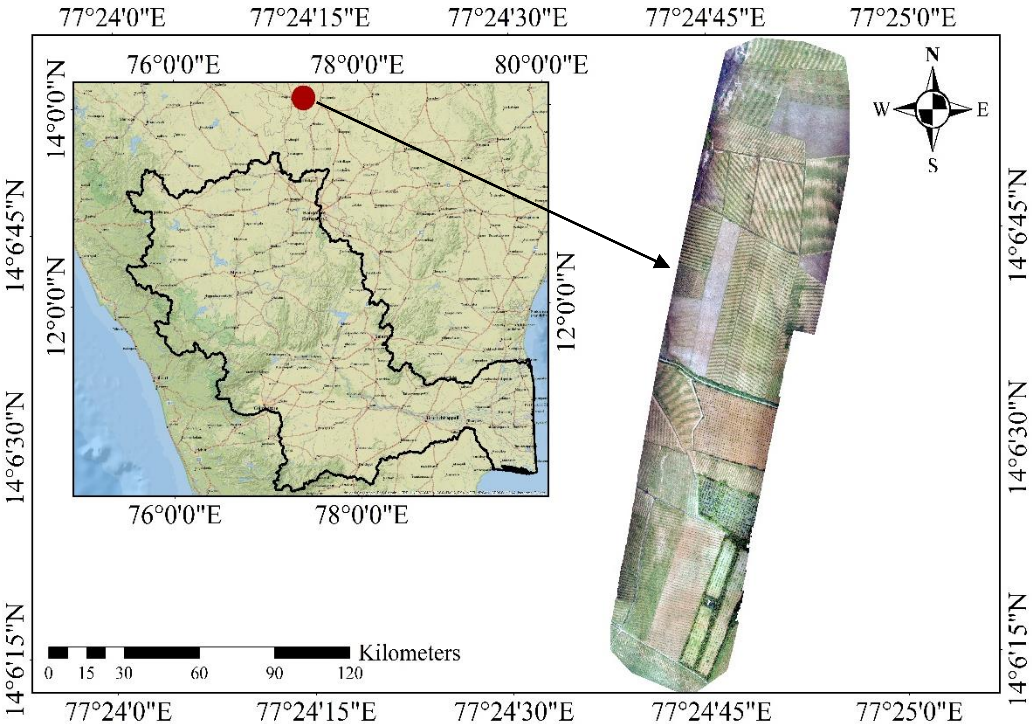

Fig. 2. UAV imagery of agricultural fields in Gowrajupalli Roddam, Anantapur District, Andhra Pradesh (https://geonadir.com/).

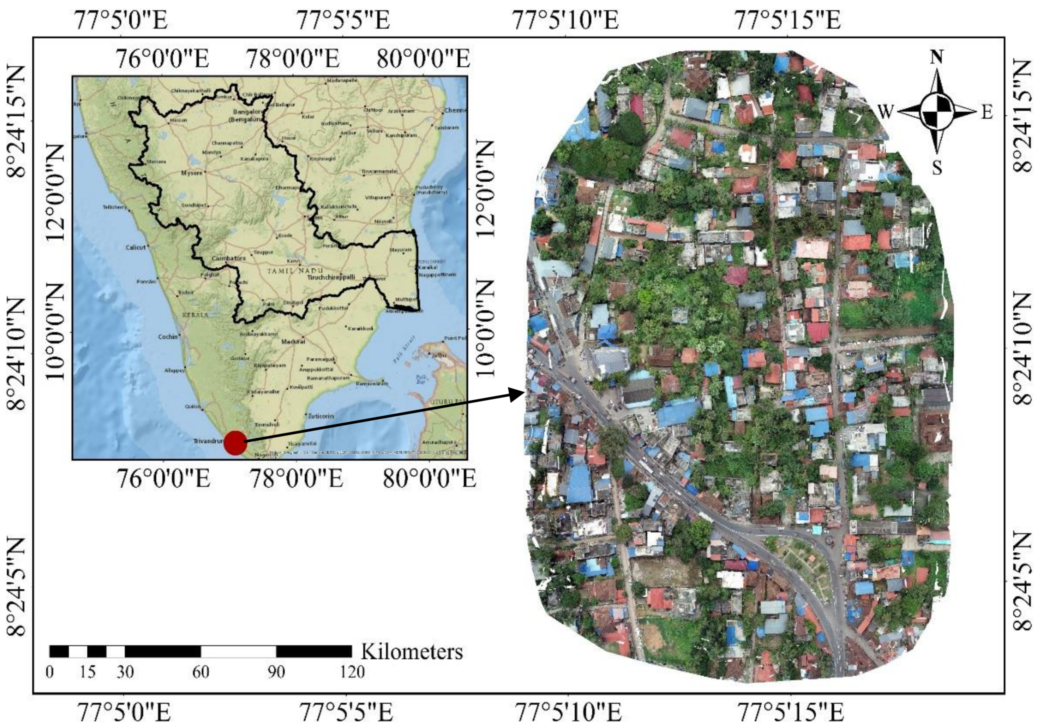

Fig. 3. UAV-captured data obtained from the DJI-EP800 sensor at Pulimoodu Junction, Thiruvananthapuram, Kerala, showcasing high-resolution imagery acquired in February 2023 (https://geonadir.com/).

4.2. Open Aerial Map

Open Aerial Map (OAM) is a community-driven mapping initiative that curate aerial imagery from diverse sources and locations. The platform serves as a repository for both new and existing drone imagery, making all images openly accessible to users. Through OAM, contributors can upload and share aerial data, fostering collaboration and innovation in mapping practices (https://openaerialmap.org/). Among the available open-source images, only one is located within the CRB (Fig. 4), while the rest are outside its boundary. Selected open-source images located near the boundary of the CRB are presented in Figs. 5 to 9.

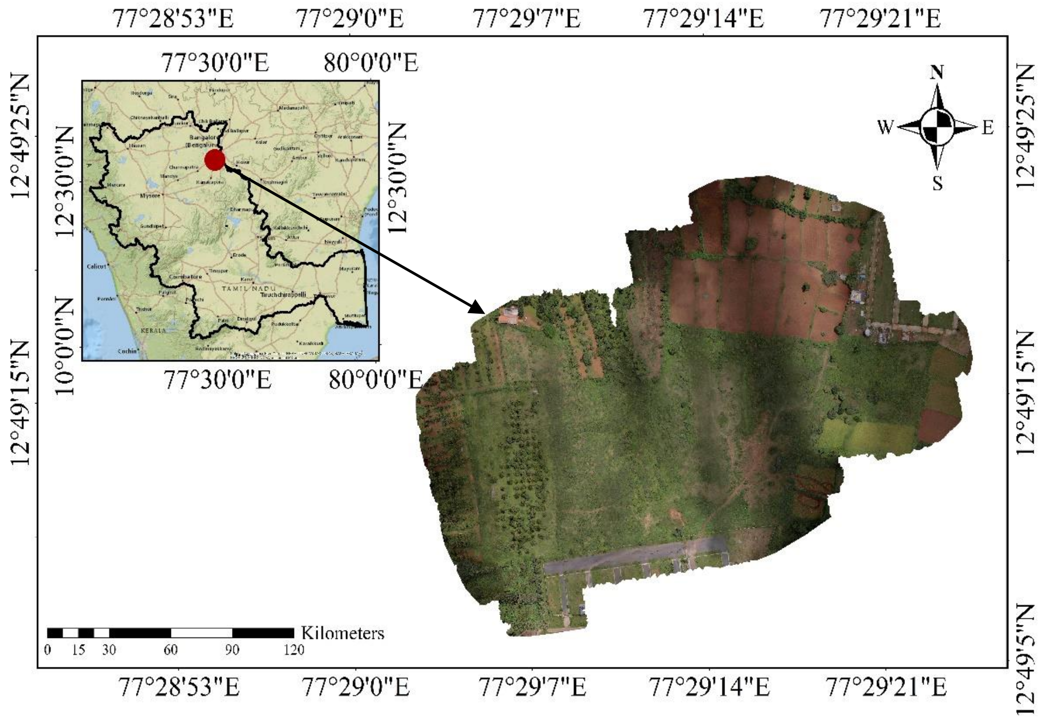

Fig. 4. UAV imagery captured by the DJI FC3411 sensor of an agricultural field in Badekatte, Bengaluru Urban, Karnataka, features a spatial resolution of 5 cm and was acquired in July 2022 (https://openaerialmap.org/).

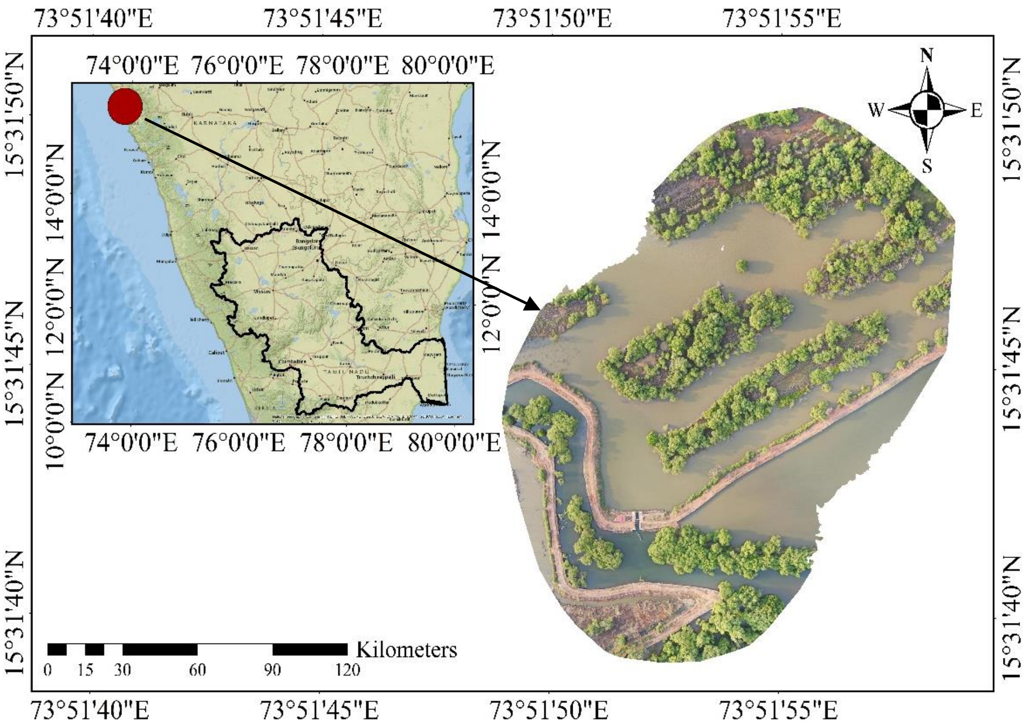

Fig. 5. UAV imagery captured by an RGB sensor of the Mapusa River, situated in Salvador do Mundo village, Bardez Taluka, Goa, spatial resolution of 2 cm and was acquired in April 2021 (https://openaerialmap.org/).

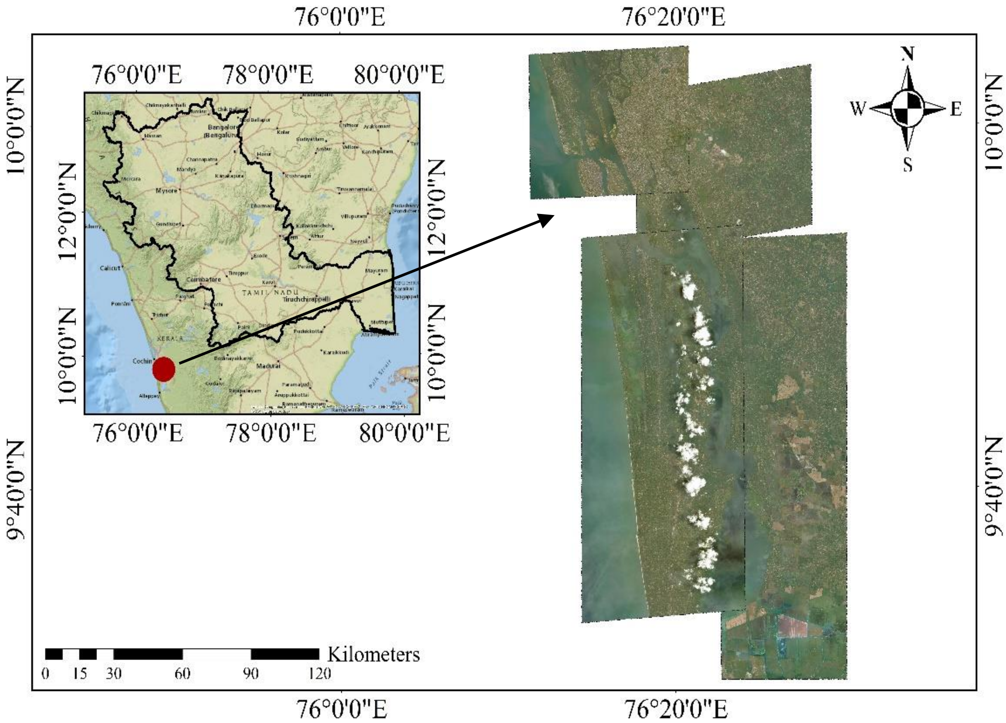

Fig. 6. The WorldView-2 images of Vadakkemuri village, located in the Kottayam district of Kerala, spatial resolution of 50 cm and were acquired between February and April 2018 (https://openaerialmap.org/).

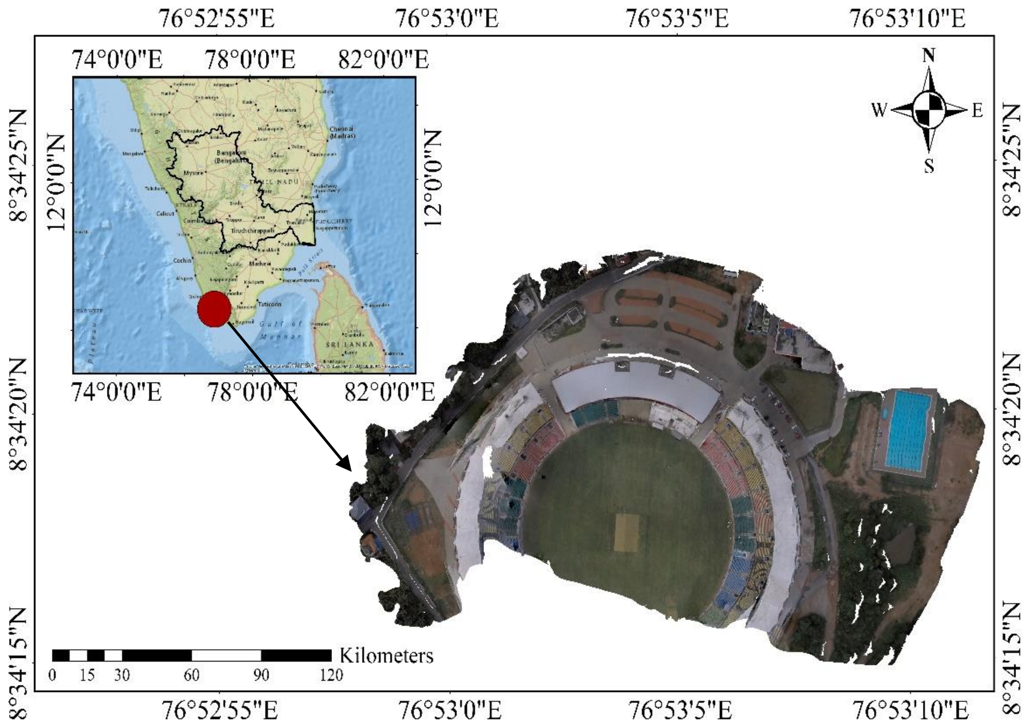

Fig. 7. UAV image captured using a GoPro HERO4 Black sensor of the Greenfield International Stadium in Trivandrum, Kerala (https://openaerialmap.org/). The image has a spatial resolution of 6 cm and was acquired in January 2015.

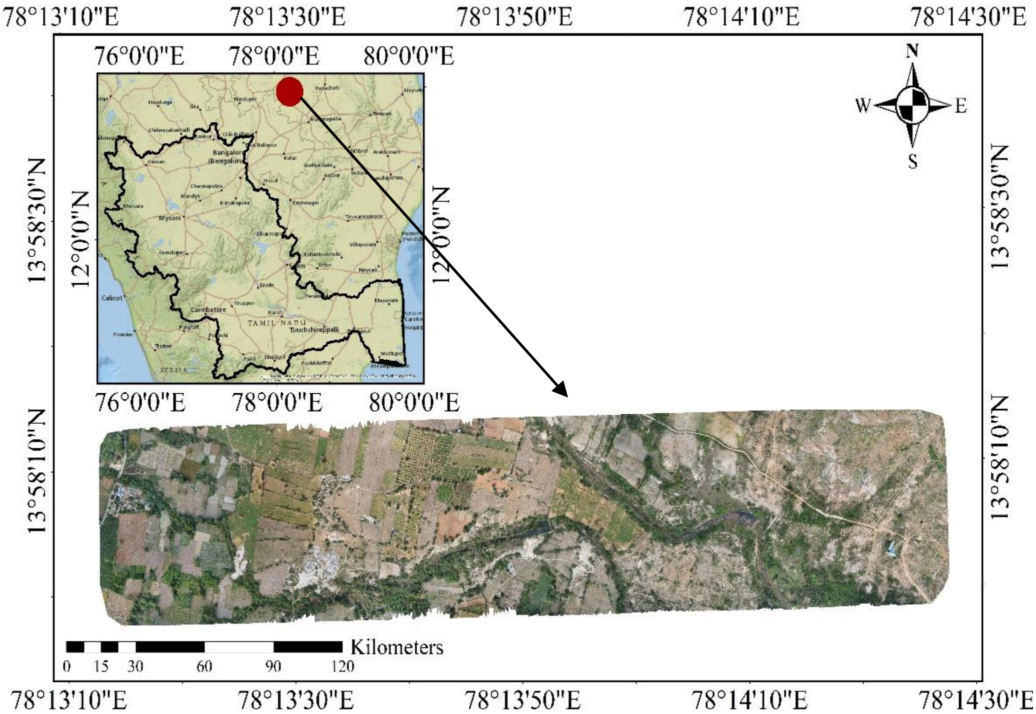

Fig. 8. UAV image captured using the DJI Mini 2 sensor in Oravoy village, Anantapur district, Andhra Pradesh (https://openaerialmap.org/). The image has a spatial resolution of 6 cm and was acquired in January 2023.

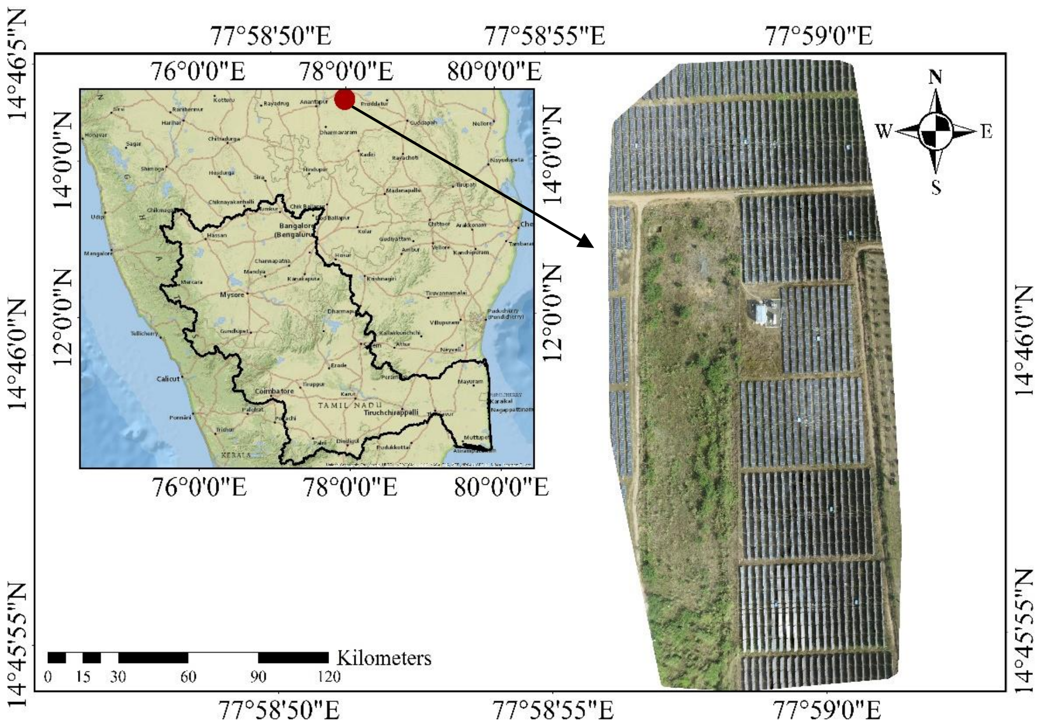

Fig. 9. UAV image of the solar photovoltaic power plant located in Komatikuntla village, Putlur, Andhra Pradesh (https://openaerialmap.org/). The image was captured with a spatial resolution of 5 cm in February 2021, providing detailed insights into the plant's layout and infrastructure.

4.3. Indian Space Research Organization (ISRO)

NESAC has successfully conducted over 60 UAV surveys to support various line departments and research initiatives in the Northeast Region (NER). Additionally, NESAC has assisted all State Remote Sensing Centres in NER in establishing UAV facilities as part of the project titled "Use of Unmanned Aerial Vehicle (UAV) Remote Sensing (UAV-RS)) for the States of NE region (NER)," which is funded by the Northeastern Council (NEC) (https://www.isro.gov.in/AerialServicesDigitalMapping.html).

Bhuvan: The ISRO's geospatial platform, Bhuvan, provides access to a variety of satellite imagery and UAV data for specific regions across India. In addition to satellite data, Bhuvan features detailed 3D models of prominent landmarks in Bengaluru, Karnataka. These include the General Post Office, High Court, ISKCON Temple, Jayadeva Hospital, Kanteerava Indoor and Outdoor Stadiums, National Games Village Complex, Nehru Planetarium, Ravindra Kalakshetra, Silk Board Junction, Town Hall, TV Tower, UB City, Vidhana Soudha, Vishveshwariah Art Gallery, and the Visvesvaraya Industrial and Technological Museum (VITM) (https://bhuvan-app1.nrsc.gov.in/globe/3d.php#).

4.4. Survey of India (SoI)

Offers UAV-based survey data for selected regions in India, particularly for projects related to mapping, infrastructure, and development. Accessible through specific project requests or government collaborations (https://www.surveyofindia.gov.in/).

5. National Projects utilizing Drone/UAV/Aerial Survey for CRB

Several national initiatives leverage drone and aerial survey technologies to enhance land management, agricultural practices, and urban planning within the CRB:

5.1. Survey of Villages Abadi & Mapping with Improvised Technology in Village Areas (SVAMITVA): The SVAMITVA scheme, launched by the Prime Minister of India on April 24, 2020, aims to provide an integrated property validation solution for rural India. The Ministry of Panchayati Raj (MoPR) is the nodal ministry for implementation, with the Revenue or Land

Records Department in each state coordinating with the State Panchayati Raj Department. The Survey of India serves as the technology partner.

This scheme utilizes drone surveying technology to demarcate rural abadi (settlement) areas, creating a 'record of rights' for households in inhabited rural areas. This initiative enables homeowners to leverage their property as a financial asset, facilitating access to loans and various financial benefits from banks. (https://www.surveyofindia.gov.in/pages/svamitva).

According to the SVAMITVA Scheme, drone surveys have been conducted for certain villages in Karnataka and Puducherry, as detailed in Table 3.

Table 3. Status of Drone Surveyed Villages through SVAMITVA Scheme (**Source:** https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2003524)

S.No.	State/UT	Notified Villages	Drone flying Completed in villages
1.	Karnataka	30715	8758
2.	Kerala	1415	298
3.	Tamil Nadu	3	3
4.	Puducherry	96	96

5.2. Tamil Nadu Sustainable Urban Development Project: This project comprises three key components: the Urban Governance Component, the Urban Sector Technical Assistance Component, and the Urban Investment Component. The Urban Governance (Model City) Component and the Urban Sector Technical Assistance Component are managed by the Commissioner of Municipal Administration, while the Urban Investment Component is implemented by Tamil Nadu Urban Infrastructure and Financial Services Limited. As part of the project, drone-based aerial surveys are utilized for urban mapping to enhance city planning, water resource management, and infrastructure development efforts (https://www.tnurbantree.tn.gov.in/tnsudp/#:~:text=Tamil%20Nadu%20Sustainable%20Urban%20Development%20Project%20(TNSUDP)%20is%20being%20implemented,Component%20and%20Urban%20Investment%20Component).

5.3. Kisan Drone Yojna: The scheme aims to promote technology in agriculture by providing financial assistance to farmers for purchasing drones. With these drones, farmers can easily spray manure, fertilizers, nutrients, and pesticides in their fields. Scheduled caste, scheduled tribe, small and marginal farmers, farmers from North-Eastern states, and women are eligible for up to ₹5 lakh or 50% financial assistance. Farmers from other areas receive up to ₹4 lakh or 40%. Farmer Producer Organizations (FPOs) are eligible for up to 75% assistance, while institutions like Indian Council of Agricultural Research (ICAR), Krishi Vigyan Kendras (KVKs), State Agricultural Universities (SAUs), and government agricultural bodies can receive grants of up to ₹10 lakh or 100% (https://pmkisannidhi.com/pm-kisan-drone-yojana-2024/).

5.4. **Digital Resurvey of 1550 Villages in the State:** The digital resurvey of 1,550 villages in Kerala is a government initiative aimed at establishing an Integrated Land Information and Management System (ILIMS). Conducted in phases, the project will cover 400 villages in the first two phases and is expected to be completed in four years. Utilizing advanced survey equipment like Real Time Kinematic (RTK) Rovers, Robotic Total Stations, and Tablet PCs, the project combines drone-plus-LIDAR mapping and other methods for accuracy. An online portal, "Ente Bhoomi," offers land-related services and project information. The initiative also introduces a common deed format for property registrations and provides real-time updates on ownership changes between the Registration, Revenue, and Survey departments (https://rebuild.kerala.gov.in/rki-projects/digital-resurvey-of-1550-villages-in-the-state-phase-1/).

5.5. **International Centre for Free and Open-Source Software (ICFOSS):** ICFOSS is an autonomous organization established by the Government of Kerala, India. Its mandate encompasses promoting Free and Open-Source Software (FOSS) for widespread use, building on the initial FOSS initiatives in Kerala, and fostering collaborations with various countries, communities, and governments to advance the FOSS movement. ICFOSS is an autonomous organization established by the Government of Kerala, India. Its mandate encompasses promoting FOSS for widespread use, building on the initial FOSS initiatives in Kerala, and fostering collaborations with various countries, communities, and governments to advance the FOSS movement.

i. **Mapping Canal System within Thrissur Kole Wetlands:** The canal system connecting the Bharathapuzha and Chalakudy rivers is a vital water source for the 13,000-hectare paddy fields in Thrissur Kole Wetlands, which supply 40% of Kerala's rice. ICFOSS used UAV mapping and field surveys to estimate the canals' total water holding capacity, optimizing seasonal cultivation for higher yields. The project successfully mapped 4,226 hectares and showcased drone technology's potential in the agro-industry.

ii. **Drone-based Land Use mapping at Niranam Grama Panchayath:** ICFOSS partnered with Grameena Padana Kendram, an agency focused on local development spatial planning, to introduce UAV mapping. High-resolution drone imagery was used to survey 180 acres in Niranam Grama Panchayath, Pathanamthitta. The proof of concept (POC) demonstrated successful integration of drone technology in local development.

iii. **Topographical Mapping and Volumetric Analysis at Vagamon Hills:** A pilot project at Vagamon Hills, Idukki, involved UAV-based topographic mapping for high-accuracy terrain modeling. 3D models were created, and grid-based cut-and-fill volume calculations were performed, showcasing the utility of drone data in topographical analysis.

iv. **3D Modelling and Mapping at Karakulam Grama Panchayath:** ICFOSS explored the use of RGB-based photogrammetry for watershed and agricultural planning. Mapping 10 acres of watershed basins and stream channels with various drones, geotagged images were processed to create a 3D model. This model was further analyzed for agricultural planning using sunlight-shadow simulations, considering slope and azimuth.

v. **Corridor Mapping at Kariavattom-Thrippadapuram Road:** As part of the Rebuild Kerala initiative, ICFOSS conducted a UAV-based mapping of a 1 km stretch of the Thrippadapuram Road to assess road conditions and flood damage after a disaster. High-resolution drone imagery provided critical insights for infrastructure rebuilding and flood damage assessment.

vi. **Empowering Farmers through Drone System for Precision Agriculture in Cuddalore District:** This initiative, under the Farm Sector Promotion Fund and implemented by Krishi Vigyan Kendra, Tamil

Nadu Agricultural University, Cuddalore, aims to promote drone spraying systems through demonstrations and training sessions. It also encourages the formation of farmer enterprises to adopt and hire drone services, fostering expertise in drone technology among farmers.

6. Approximate Cost of Data Acquisition for CRB

This section presents an estimated cost breakdown for two organizations, namely Ocean Square and Aeroflutter Techlabs, related to acquiring drone survey data for the proposed project. Further information about these organizations is provided in Table 4, while Table 5 offers an approximate cost estimate for data acquisition.

Table 4: Drone survey companies with corresponding names and addresses

S.No.	Name and address of the companies	
1.	**Ocean Square** (https://oceanssquare.com/) Manikanda Bharath K, Consultant, Ocean Square, Chennai-25 Mobile No.: +91-8940295211 Email: oceansquare.survey@gmail.com	**Aeroflutter Techlabs** (https://aeroflutter.com/) 40, Dhanvantri Nagar, Ramnamaroti, Nagpur, Maharashtra, India 440024 Mobile No.: +91 8793188229 | +91 8087805452 Email: info@aeroflutter.com

Table 5: Price estimates for drone survey of Ocean Square and Aeroflutter Techlabs companies

<table>
<tr><th rowspan="2">S. No.</th><th rowspan="2">Type of data processing</th><th rowspan="2">Specific data</th><th>Ocean Square</th><th>Aeroflutter Techlabs</th></tr>
<tr><th colspan="2">Price* (per sq. km)</th></tr>
<tr><td>1.</td><td>DEM Creation</td><td>DEM Creation: Generating DEMs from classified point clouds to represent the terrain.</td><td rowspan="4">Rs. 35,000 + 18% GST</td><td rowspan="4">Rs. 3,500 + 18% GST</td></tr>
<tr><td>2.</td><td>DSM Creation</td><td>DSM Creation: Creating Digital Surface Models (DSMs) to capture the surface of objects (e.g., buildings, vegetation) above the ground.</td></tr>
<tr><td>3.</td><td>Contour Generation</td><td>Contour Generation: Producing contour lines from DEMs for topographic analysis.</td></tr>
<tr><td>4.</td><td>Topographical Survey DGPS and Drone with centimetre accuracy (for more than 100 sq. km)</td><td>• Orthomosaic
• Dense Point Cloud (.laz/.las)
• RSME Report
• 3D Surface Model
• GIS-Based Map / .dwg
• Shape File / KML File
• GCP CSV Data with Both Projections (GCS & PCS)</td></tr>
<tr><td>5.</td><td>Point Cloud Data (LiDAR)</td><td>Point Cloud Classification: Distinguishing different types of points (e.g., ground, vegetation, buildings) to improve the accuracy of subsequent analysis</td><td rowspan="3">Rs. 60,000 + 18% GST</td><td rowspan="3">Rs. 6,500 + 18% GST</td></tr>
<tr><td>6.</td><td>Feature Extraction Object Detection</td><td>Object Detection: Identifying and classifying objects such as buildings, roads, and vegetation from LiDAR or photogrammetric data.
Change Detection: Analysing temporal changes in the landscape by comparing current data with historical datasets.
Topographic Analysis: Identifying landforms, slopes, and drainage patterns for environmental and planning purposes.</td></tr>
<tr><td>7.</td><td>GIS Integration</td><td>Georeferencing: Aligning drone and LiDAR data with spatial reference systems to ensure proper location accuracy.
Spatial Analysis: Performing operations like buffering, overlay analysis, and proximity analysis to derive insights from geospatial data.</td></tr>
</table>

		Data Visualization: Creating maps, charts, and other visual aids to effectively communicate findings.		
8.	**Lidar Survey**	• DTM/ DEM/ DSM • Tile Photos • RMSE Report • Contour • 3D Surface Model		Rs. 4,500 + 18% GST
9.	**Thematic Mapping Land Use/Cover Mapping**	Identifying and classifying land use or land cover types based on remote sensing data. Vegetation Analysis: Assessing vegetation health, density, and distribution using spectral and LiDAR data. Understanding these types of GIS processing tasks can help you effectively scope out and execute drone and LiDAR mapping projects. Each type of data and processing method contributes to a comprehensive understanding of the surveyed area, aiding in decision-making for planning, analysis, and management.	-	Rs. 3,500 + 18% GST
10.	**Data Management and Quality Control Data Cleaning**	Removing noise and erroneous data points from LiDAR point clouds or imagery. Data Fusion: Combining data from multiple sources (e.g., different drone flights or sensors) to create a comprehensive dataset. Metadata Management: Ensuring that all data is properly documented with metadata for future reference and use.	-	Rs. 2,000 + 18% GST
11.	**Data Acquisition**	with PPK VTOL	Rs. 25,000 + 18% GST	Rs. 4,000 to 7,000 + 18% GST, depending on terrain, GSD, etc.
12.		with PPK Multirotor	Rs. 16,000 + 18% GST	

*** Price estimates vary based on the type of sensors utilized, the resolution (ground sampling distance), and other factors.**

7. Summary

Aerial photographs and drone imagery are indispensable tools in the management and preservation of the CRB, offering high-resolution, real-time data essential for a range of critical applications. These technologies allow for the detailed and accurate mapping of the basin’s complex topography, including river channels, floodplains, and catchment areas, which are crucial for understanding the hydrological dynamics of the region. By providing timely data on river flow rates, reservoir levels, and areas susceptible to flooding, aerial and drone surveys enhance the planning and execution of flood control measures, ensuring the efficient management of water resources, especially during monsoon seasons and extreme weather events.

In addition to water management, drone imagery plays a vital role in monitoring environmental changes across the basin. The ability to track land-use transformations, such as deforestation, agricultural expansion, and urban development, provides valuable insights into how these changes impact the hydrological balance and ecological health of the region. For example, drones can be deployed to assess the sedimentation in rivers and reservoirs, which directly affects water storage capacity and the quality of water available for agricultural and domestic use. Regular monitoring of sedimentation patterns also helps in devising strategies to mitigate erosion and maintain the functionality of water bodies.

Furthermore, drone-based surveys are instrumental in agricultural management, enabling precision farming practices within the basin. High-resolution imagery allows for the identification of crop health variations, soil moisture levels, and irrigation efficiency, leading to optimized water use and improved crop yields. In a region where agriculture is heavily dependent on water from the Cauvery River, these technologies provide farmers and water managers with the data needed to make informed decisions that minimize water wastage and enhance productivity.

Beyond immediate water and agricultural management, aerial and drone imagery also support long-term conservation efforts within the CRB. These technologies can be used to identify critical ecological zones, such as wetlands and biodiversity hotspots, that require protection from human activities. By continuously monitoring changes in land cover and vegetation patterns, decision-makers can implement conservation strategies that safeguard the basin’s natural resources and ecosystems.

Overall, the integration of aerial photographs and drone imagery into the management of the CRB represents a forward-looking approach that not only enhances day-to-day resource management but also contributes to the basin's long-term sustainability. By providing precise, comprehensive, and real-time data, these technologies support more effective decision-making processes, ensuring that water resources, agricultural practices, and environmental conservation are managed in a balanced and sustainable manner.

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